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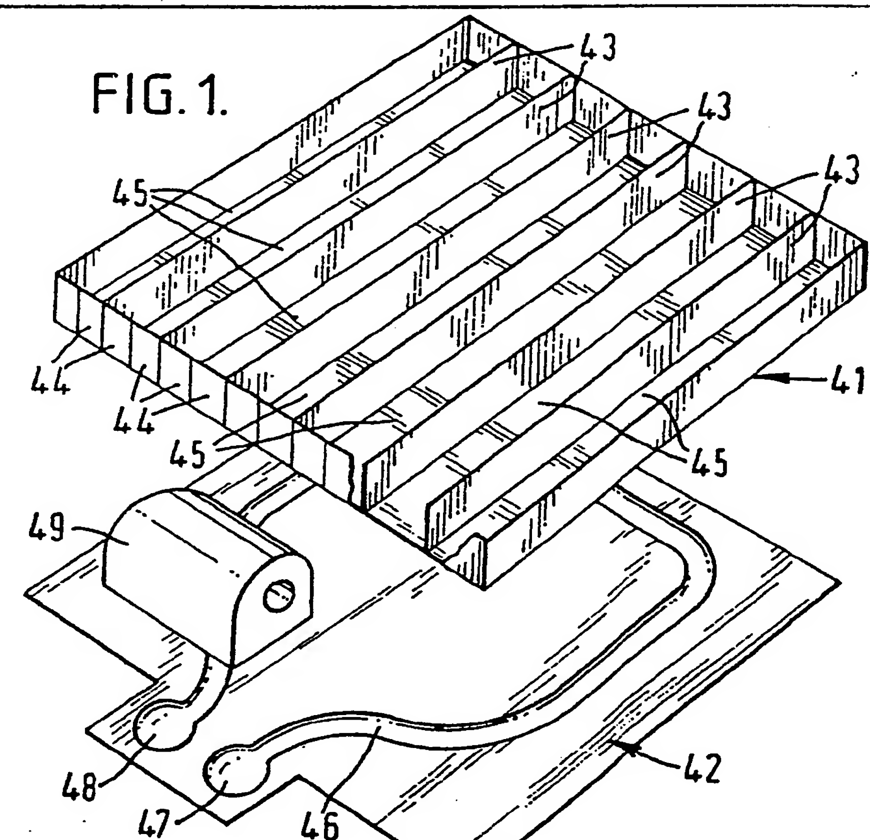
(54) A heat pump unit

(57) A heat pump unit comprises at least one tray having a front sheet (41) folded so as to form a series of partitions (43) two sheet thick, extending away from the remaining portion of the sheet and a back sheet (42) having a channel (46) therein, said sheet being attached to the face of the front sheet (41) remote from the partitions (43) so that the channel together with said face of the front sheet forms a continuous passageway traversing a major proportion of that part of the area of the front sheet occupied by partitions. Alternatively the heat pump unit comprises at least one tray, said tray comprising a central sheet attached to one face of which is a front sheet slitted to enable the sheet to be folded upwards so as to form a series of partitions and attached to the other face of which is a back sheet having a channel therein which together with this other face forms a continuous passageway traversing a major proportion of that part of the area of the central sheet occupied by the enclosures formed between the partitions.

POOR QUALITY

FIG. 1.



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.
This print takes account of replacement documents later filed to enable the application to comply with the formal requirements

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FIG. 1.

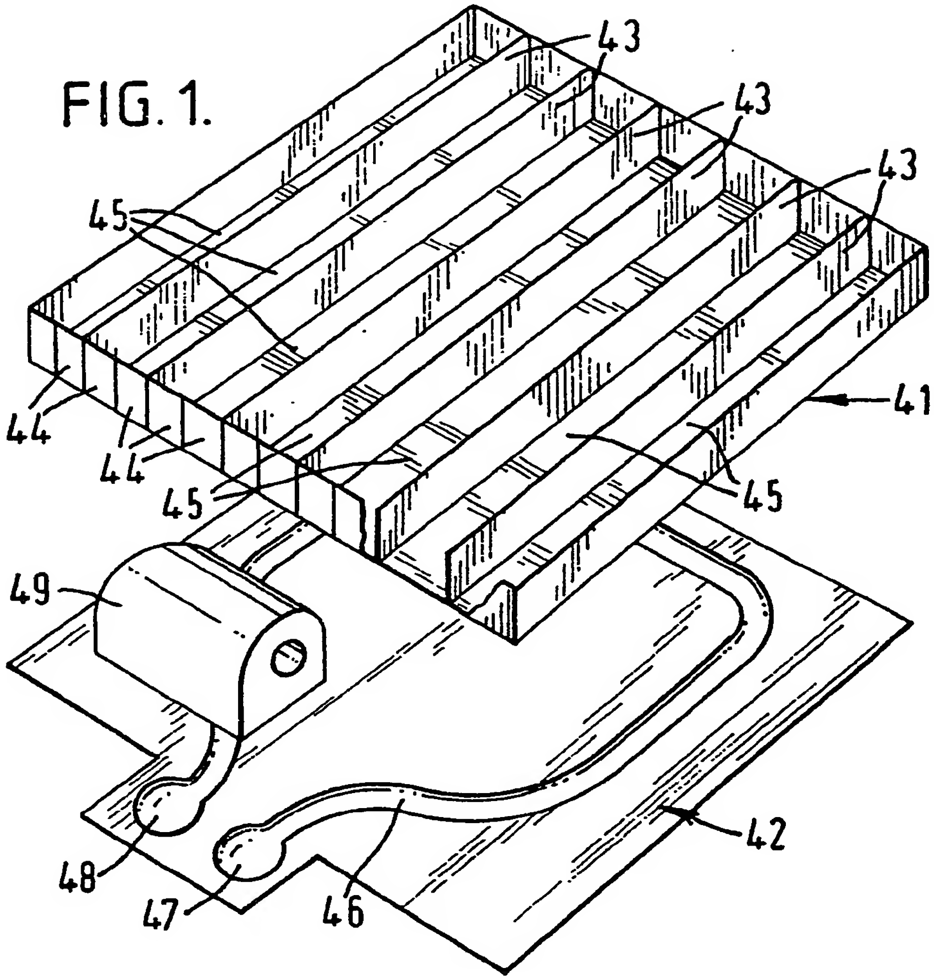

FIG. 2.

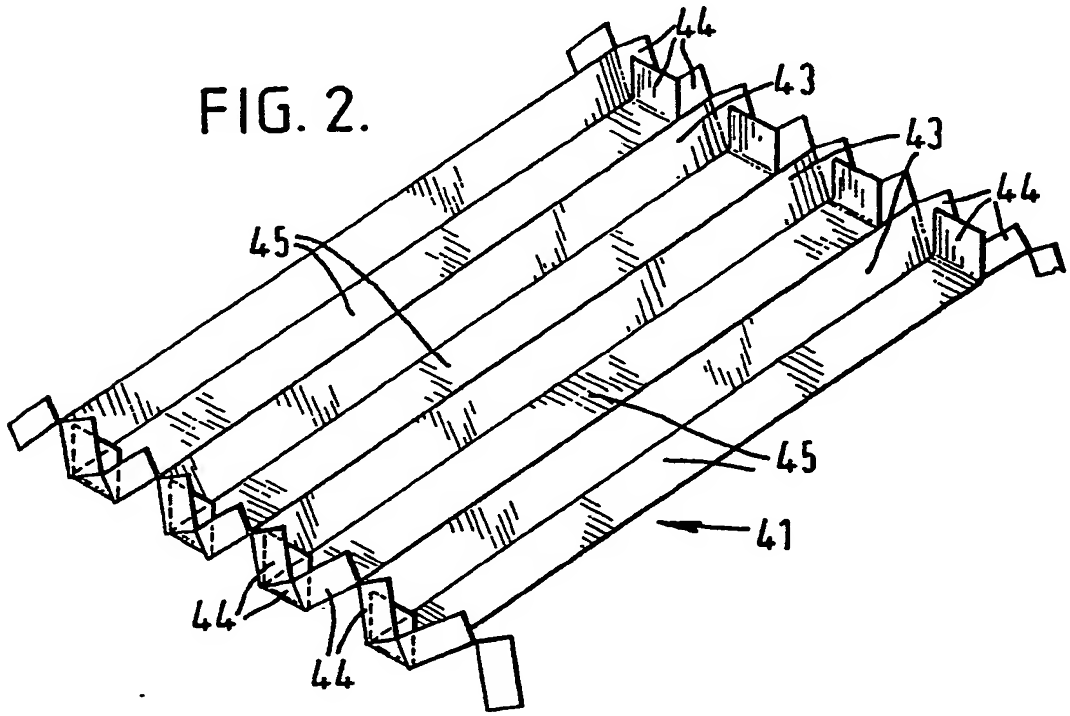

FIG. 3.

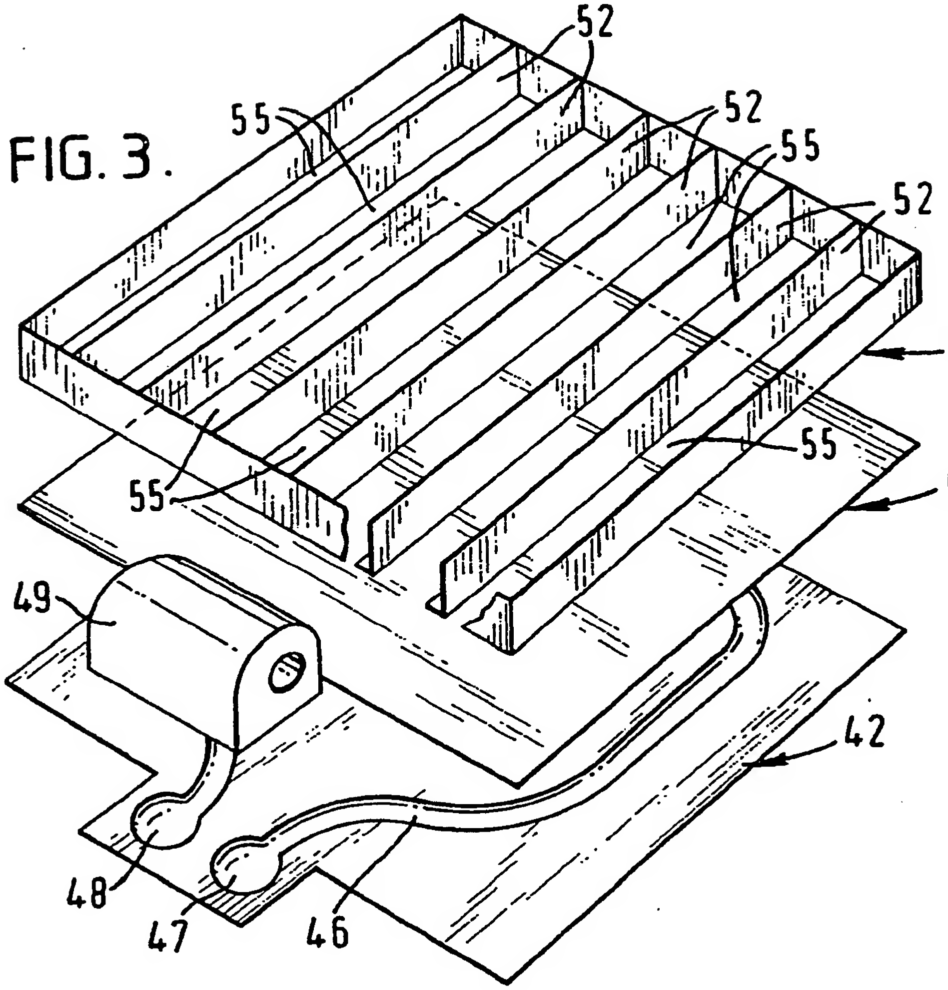
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FIG. 4.

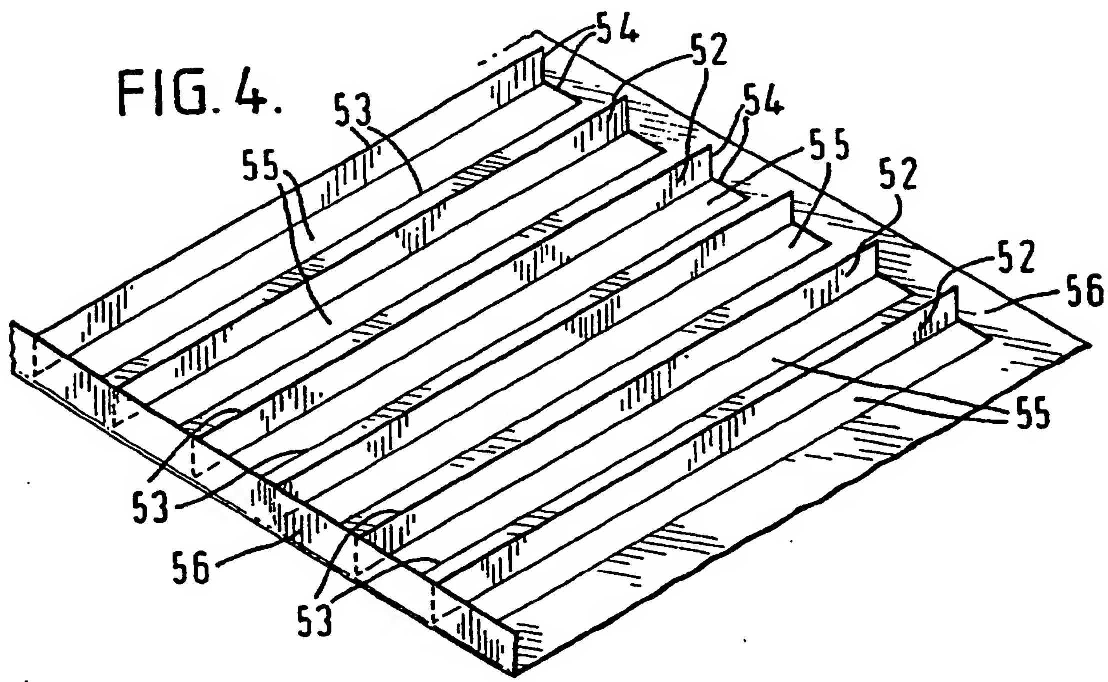
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FIG. 5.

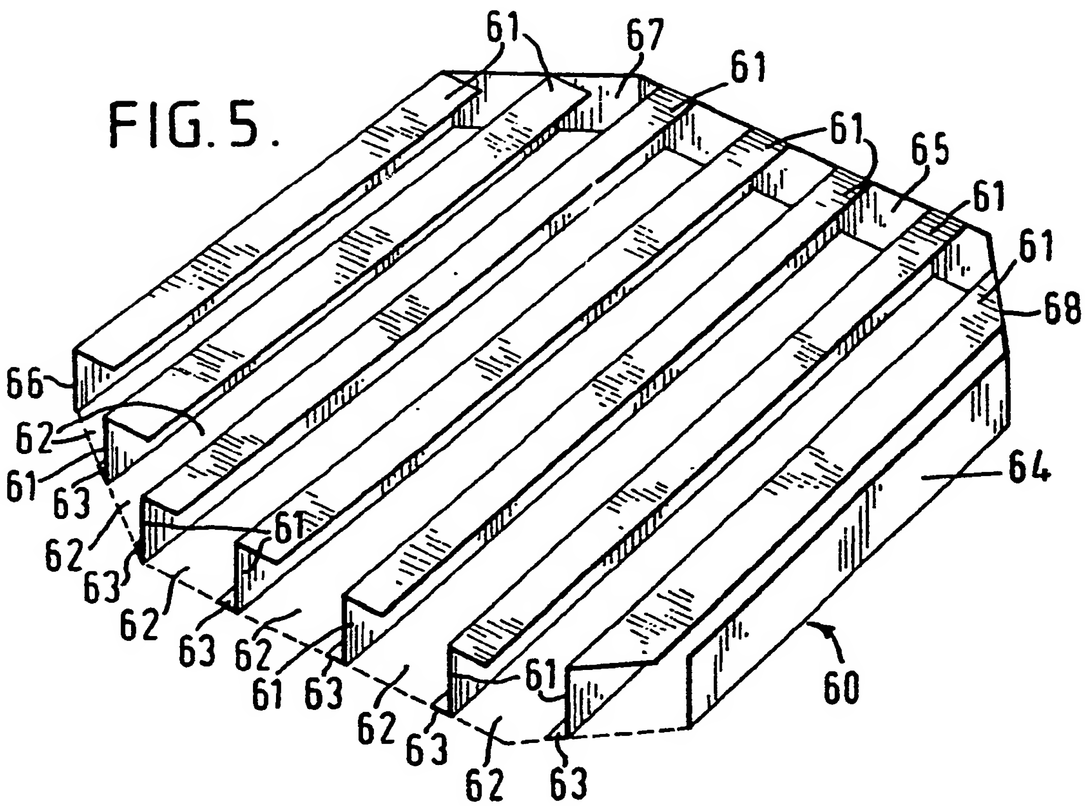
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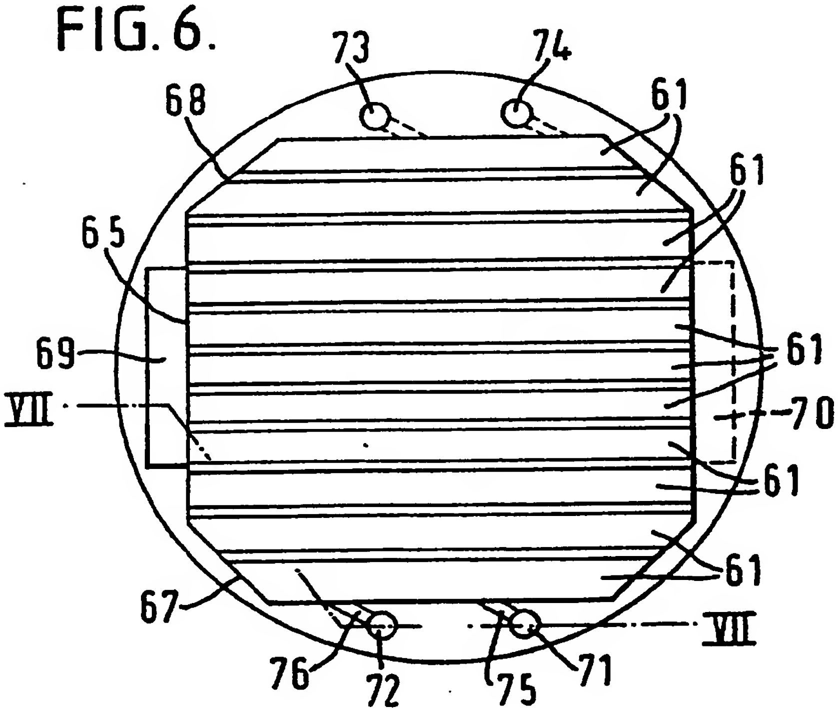
FIG. 6.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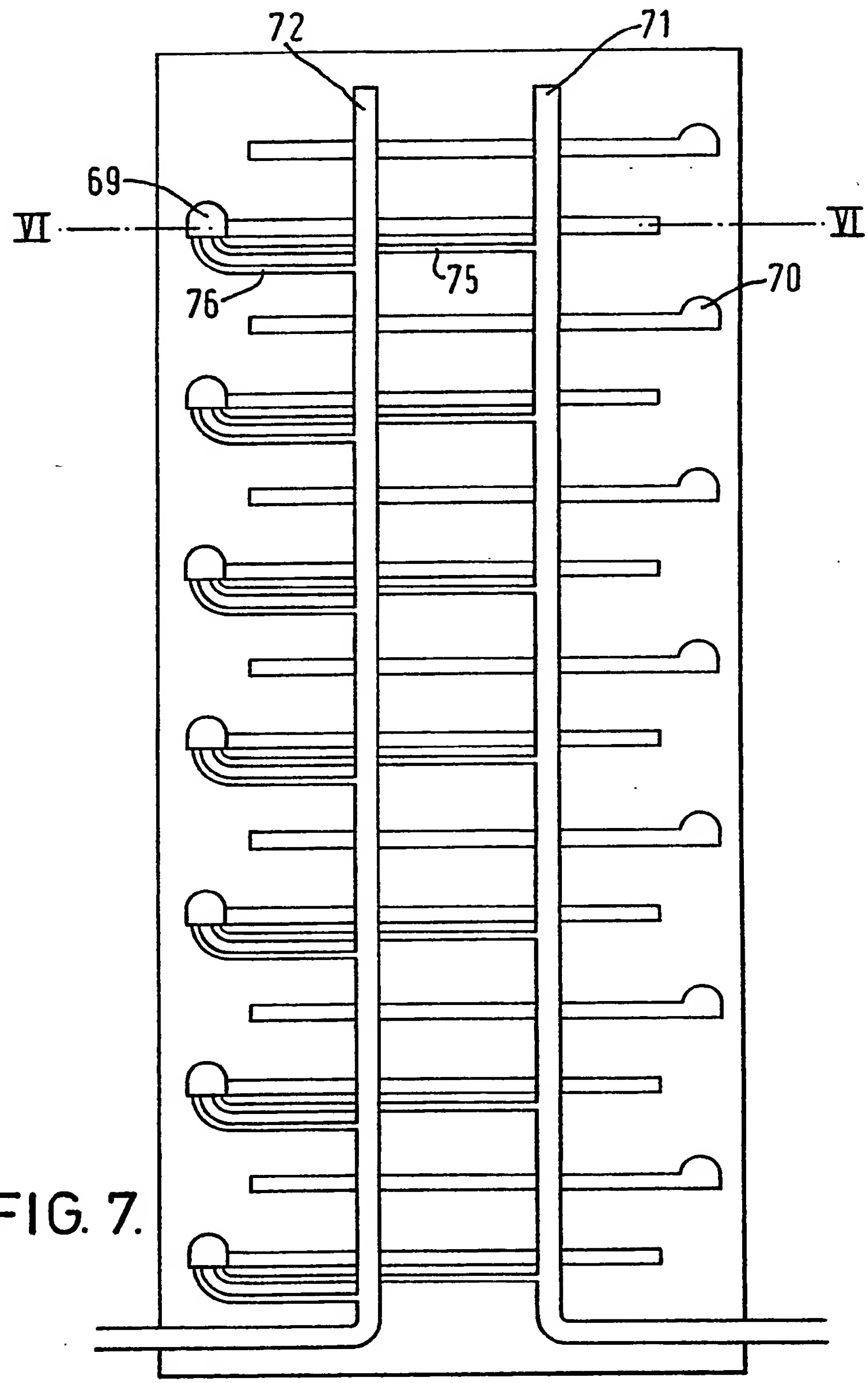

FIG. 7.

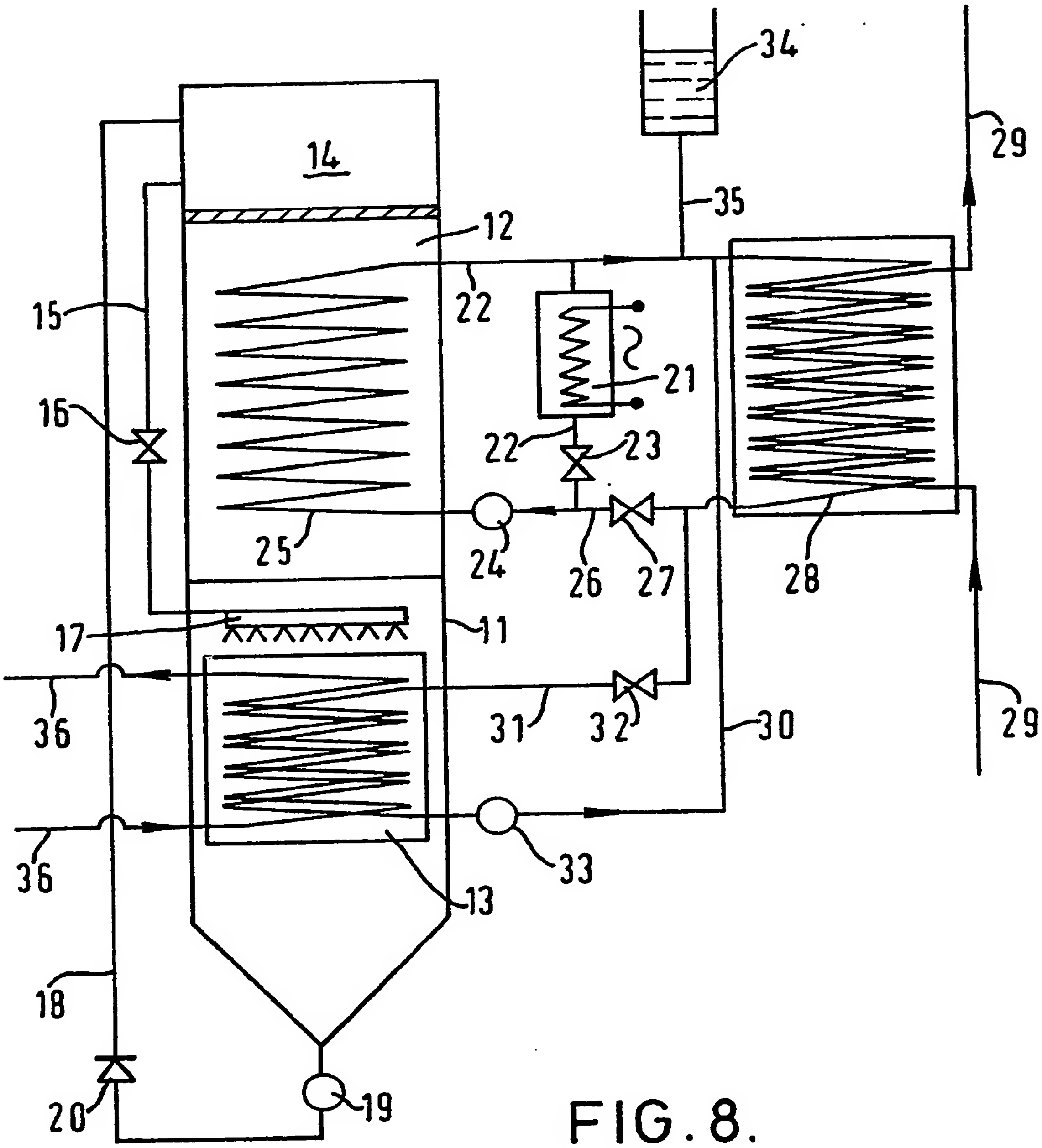
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FIG. 8.

SPECIFICATION

A heat pump unit

This invention relates to heat pump units which can act as adsorbers/desorbers or evaporators/ condensers.

Adsorbers/desorbers are often used in heat pumps where an adsorbate such as water or an azeotrope, e.g. of water and n-propanol, is adsorbed by an adsorbent such as zeolite molecular sieve, during which process heat of adsorption is evolved. Many of the adsorbents are granular or powders and it is necessary to provide means whereby these adsorbents can be readily housed in the adsorber so that the adsorbate has ready access to the adsorbent but so that the adsorbent does not become a glutinous mass when fully charged with adsorbate. Also it is desirable to provide an adsorber/desorber or an evaporator/condenser which can be constructed relatively cheaply. It is also necessary to maintain a vacuum within the heat pump casing so it is desirable that there should be no joints other than welded ones and that there should be no gland seals, either for spindles or for electrical connections.

According to this invention a heat pump unit which meets these criteria is one comprising at least one tray which comprises a front sheet folded so as to form a series of partitions, two sheet thick, extending away from the remaining portions of the sheet. There is also a back sheet having a channel therein attached to the face of the front sheet remote from the partitions so that the channel together with said face of said front sheet forms a continuous passageway traversing a major proportion of that part of the area of the front sheet occupied by the partitions.

If desired the front and back sheets could be attached to but separated by a central or septum sheet. This would mean that the continuous passageway would be formed by the face of the central sheet remote from the partitions and the channel of the back sheet.

As an alternative embodiment the heat pump unit could be one comprising at least one tray, said tray comprising a central sheet attached to one face of which is a front sheet slitted to enable the sheet to be folded upwards so as to form a series of partitions. Attached to the other face of the central sheet is a back sheet having a channel therein which together with this other face forms a continuous passageway traversing a major proportion of that part of the area of the central sheet occupied by the enclosures formed between the partitions.

The tray will usually be made of metal, although it could be made of high melting plastics material provided it has a thermal conductivity comparable with metal. The metal can be for example stainless steel or carbon steel, brass or copper. When made of metal the various components of the tray will usually be welded, brazed or even glued together.

When used the central sheet which is substantially flat, will usually be ..quare or rectangular with its corners cut off although it could for example be circular.

The sheet which is folded is preferably folded so as to form a series of substantially parallel partitions which are also substantially parallel to two edges of the sheet when the sheet has parallel sides. These partitions extend upwards when the central sheet is laid flat and usually they will be 4 to 10 cm high.

In order to improve the thermal conductivity of the tray especially in the case of the unit's use as an evaporator/condenser it is highly desirable if the partitions are turned through approximately a right angle before they terminate. In other words they have a portion substantially parallel to the back sheet. When the unit is used as an evaporator/condenser the thermal conductivity can be still further increased if a matrix of metal fibres, e.g. wire wool, is inserted into the volumes bounded on three sides by the bent partition and the front sheet. This wire wool should be made of a substance not corroded by the adsorbate, e.g. stainless steel, copper, bronze, etc.

It is desirable to provide some side walls to the areas bounded by the partitions. Therefore when using only a front and a back sheet it is preferred that the sheet which is folded is also cut at the sides which are perpendicular to the folds. The cuts should extend to a distance equal to the height of the partitions or the height of the upright part of bent partitions, and should be parallel and made along the folds. In this manner these cut end pieces can be folded in a direction, at right angles to the folded partitions and welded or otherwise fixed together to form side walls joining up with the folded partitions so as to form enclosures.

As an alternative to slitting this sheet, separate sheets can be welded or otherwise attached to the ends of sheet and to the folded partitions so as to form the side walls.

In the alternative embodiment of the invention the front sheet has to be slitted and folded. This is preferably achieved by producing a series of substantially parallel and equispaced slits in a square or rectangular sheet with cut-off corners, each slit being spaced apart at a distance substantially equal to sum of the width of the folded portions and the width of the enclosure desired and each slit terminating at a distance from the side of the sheet substantially equal to the height of the enclosure desired. There are also a series of short slits at right angles to and meeting the series of substantially parallel slits, the length of these short slits being equal to the height of the folded portions. This enables parts of the sheet to be pulled up to form a series of parallel partitions which are joined at their ends to the edges of the sheet perpendicular to these partitions after they have been folded through 90°.

The back sheet is one which has channel therein so that when it is welded or otherwise fixed to the front sheet or the central sheet it forms a continuous passageway traversing a major portion of that area of the front or central sheet

occupied by the partitions. This passageway will of course be on the face of the front sheet or the face of the central sheet remote from the partitions or enclosures. The passageway should traverse a major proportion of the area occupied by the partitions so that there is a maximum heat transfer from or to the heat transfer fluid flowing through the passageway to or from the enclosures between the partitions.

It is convenient if the passageway can be provided with an inlet and outlet. This can be achieved by extending the area of the back sheet and providing on the extended portion of the back sheet a canopy with an inlet and outlet, the inlet and outlet connecting with the two ends of the passageway in the back sheet.

The heat pump unit will usually include a large number of trays, e.g. between 15 and 25, for example 20. These are stacked above each other fairly close together, but not so close that vapour cannot reach an adsorbent housed in the enclosures.

In order to facilitate the assembly of the stack of trays in the adsorber, it is preferable when there are extended portions on the back sheet if each tray is stacked so that the extended portions alternate in position and there are four vertical pipes to carry the heat transfer fluid to and from the trays.

Usually the outer casing of the heat pump unit will be cylindrical in which case the trays will preferably be square with their corners cut off so as to fit inside the circular area of cross-section of the casing. This will leave four segmental spaces and it is preferred that one pair of opposite segmental spaces houses the vertical pipes, two pipes being located in each space. With these four vertical pipes, two can connect with the inlets and outlets of the passageways of one set of alternately mounted trays and the other two can connect with the inlets and outlets of the passageways of the other set of alternately mounted trays.

In the preferred embodiment where the extended portions of the trays alternate, where the trays are substantially square with their corners cut off and where the casing of the heat pump is cylindrical the vertical pipes connecting with the inlets and outlets of each tray can only occupy the pairs of opposite segmental spaces which are at right angles to the pairs of opposite segmental spaces partially occupied by alternating extended portions of the trays.

In this preferred embodiment when the heat pump unit is used as an evaporator/condenser, it is only necessary to have three side walls per tray plus side walls for the four portions cut-off at the corners. The one side not having walls is that side over which adsorbate flows. The side walls can be made in the manner previously suggested according to the form of tray. One or two of the side walls can merely be part of the front sheet turned upward. Likewise the side walls of the cut-off corners can be part of the front sheet turned upwards.

When the heat pump unit is used as an adsorber/desorber these volumes bounded by the folded partitions and front sheet will be occupied by adsorbent.

Usually the adsorbent will be a zeolite molecular sieve, e.g. Y-zeolite molecular sieve, but sometimes it could be activated charcoal. Usually it is particulate or granular and it can be seen that the enclosures formed by the folded front sheet will readily house such materials. Sometimes, e.g. when using an azeotrope as adsorbate, the enclosures may contain a bottom layer of for example Y-zeolite nolecular sieve and a top layer of activated charcoal.

When the heat pump unit is used as an adsorber it may be used in conjunction with a condenser and an evaporator e.g. other heat pump units of this invention. In processes of pumping heat using such heat pump units, adsorbate is desorbed from adsorbent housed in a heat pump unit acting as an adsorber and the desorbed adsorbate allowed to condense onto a heat pump unit acting as a condenser. The heat of condensation is transferred by heat exchange to the load. Thereafter when the desorption is completed heat is obtained from the adsorber by heat exchange and delivered to the load. After the temperature of the adsorber has been reduced to its normal adsorption temperature, adsorbate is allowed to fall onto a heat pump unit acting as an evaporator whilst low temperature heat (i.e. heat which it is desired to pump to a higher temperature) is supplied to the evaporator by heat exchange. Adsorbate is evaporated from the evaporator and the vaporised adsorbate is adsorbed by the adsorbent in the adsorber evolving heat of adsorption which is transferred to the load by heat exchange.

The invention is now described with reference to the drawings wherein

Fig. 1 shows an exploded view of one form of tray;

Fig. 2 shows a view of part of the tray of Fig. 1;

Fig. 3 shows an exploded view of an alternative form of tray;

Fig. 4 shows a view of part of the tray of Fig. 3;

Fig. 5 shows a perspective view of part of one form of square tray with its corners cut-off;

Fig. 6 is a plan view of a tray similar to that shown in Fig. 5 and is taken through line VI—VI of Fig. 7;

Fig. 7 is an elevation of a typical heat pump unit taken on line VII—VII of Fig. 6; and

Fig. 8 shows the arrangement of the components of a heat pump using heat pump unit of the invention.

Referring to Fig. 1 and 2 the front sheet is shown generally at 41 and the back sheet at 42. In Fig. 2 the front sheet 41 is shown after folding and slitting but before it is fully assembled as it is shown in Fig. 1. In particular the upright partitions 43 in Fig. 2 have not been fully completed in that the two thicknesses of sheet are not touching one another prior to being welded together. Fig. 2 shows clearly the end pieces 44 after being folded

but before they are touching prior to being welded together. In this embodiment the folded and slitted sheet itself provides the bases 45 for the enclosures.

The channel 46 on base sheet 42 provides the continuous passageway for heat transfer fluid when the front sheet 41 is welded to the base sheet 42. Of course care must be taken when welding together the upright partitions 43 to ensure that there are no gaps in the proximity of the channel 46 which would give rise to leaks of heat transfer fluid.

A canopy 49 is fixed to an extended portion of the back sheet 42 so as to cover the inlet 47 and outlet 48 of the continuous passageway 46. The canopy 49 itself is provided with a separate inlet and outlet which connect with the inlet 47 and outlet 48.

Referring now to Fig. 3 and 4 similar parts to the embodiment shown in Fig. 1 and 2 are identified by the same reference numerals and will not be described again.

In this case there is a front sheet 50 and a central sheet 51 in addition to the back sheet 42.

In this case the central sheet 51 provides the bases of the enclosures as well as cooperating with the channel 46 in the back sheet 42 to provide the continuous passageway.

As can be seen the upright partitions 52 are of single sheet thickness and are formed by the sheet being slit with long slits and short slits, the edges formed by the long slits being shown at 53 and those formed by the short slits at 54. This means that those areas shown at 55 are open. The side walls 56 are formed by folding the sheet and welding to the ends of the upright partitions 52.

Referring to Fig. 5 the folded and slitted front sheet 60 of a tray similar to that in Fig. 3 is shown, but its corners have been cut-off and the upright partitions 61 have been folded over. There are openings 62 where the partitions have been folded away from the remaining portions 63 of the front sheet 60. Although not shown in this case, there is also a back sheet with a channel therein similar to that shown in Fig. 3.

This tray is designed so that there are only three main side walls 64, 65 and 66 and side wall 65 is constructed in the same way as the side walls 56 are formed as shown in Fig. 4. Side walls 64 and 66 are formed by simply turning up part of the front sheet 60. Likewise two other subsidiary side walls 67 and 68 are formed by turning up part of the front sheet 60.

The tray part of which is shown in Fig. 5 has only three main side walls and is therefore designed primarily for use in a condenser/evaporator. In order to improve the thermal conductance the spaces bounded by the back sheet (not shown) and the uprights 61 turned through 90° are occupied by stainless steel wire wool, but these are not shown for the sake of clarity.

The tray part of which is shown in Fig. 5 can easily be adapted for use in an adsorber/desorber. Instead of the wire wool there will be adsorbent and there will be a further main side wall and two further subsidiary side walls. The main side wall will be opposite to and constructed in the same way as side wall 65 and the further subsidiary side walls will be opposite to and constructed in the same way as subsidiary side walls 67 and 68.

Referring to Fig. 6 the tray shown is in all respects similar to that shown in Fig. 5 but it has more enclosures. Similar parts are identified with the same numerals. As seen from Fig. 6 there is one canopy 69 which is attached to the extended portion of the back sheet (not shown) and this canopy covers the inlets and outlets to the passageway formed in the back sheet. The canopy 70 shown in dotted lines is that of the tray below and as can be seen from Fig. 7 the trays are arranged so that the canopies alternate in position.

Referring to Fig. 6 and 7 there are four vertical pipes 71, 72, 73 and 74 which connect with the inlets and outlets in the back plate of each tray by means of separate conduits two of which are shown at 75 and 76.

Although not shown, it is appreciated that the trays are strapped together to form an assembly which is installed in the casing. The trays are stacked so that water from one tray can drain onto the tray below.

Referring to Fig. 8 there is a vacuum casing 11 which contains an adsorber 12 comprising 20 trays according to Fig. 5 and 6 but with side walls all round and stacked above each other. These trays contain zeolite molecular sieve as adsorbent, for example A type zeolite molecular sieve. There is a heat exchanger 13 of construction similar to that shown in Fig. 5, 6 and 7 which can act as both an evaporator and as a condenser and condensed liquid can pass in series from tray to tray. At the top of the casing 11 there is a tank 14 containing water which is the adsorbate. A conduit 15 having control valve 16 connects the water tank 14 to a sprayer 17 capable of spraving liquid over the evaporator/condenser 13. There is also a conduit 18 having pump 19 and non-return valve 20 whereby liquid can be pumped from the bottom of the vaccum casing 11 to the water tank 14. One of the coils of the evaporator/condenser 13 is connected via conduit 36 to a low temperature heat transfer fluid i.e aqueous calcium chloride.

A resistive heater 21 is connected by conduit 22 valve 23 and circulating pump 24 to heat exchanger 25 housed in the adsorber 12. The resistive heater 21 is also connected through conduit 26 and valve 27 to a countercurrent heat exchanger 28. The other side of this heat exchanger 28 is connected to the domestic hot water system via conduit 29.

The evaporator/condenser 13 is also connected to countercurrent heat exchanger 28 via conduits 30 and 31, valve 32 and circulation pump 33. Also there is a heat transfer fluid reservoir 34 connected by conduit 35 to conduit 22. In this case the reservoir contains a low vapour pressure liquid, e.g. silicone liquid as heat transfer liquid.

The heat pump is operated as follows:

The resistive heater 21 is activated with valve 23 opened and valve 27 closed. The circulating pump 24 is activated and the silicone heat transfer fluid is circulated through the heat exchanger 25 in the adsorber 12. Water vapour is desorbed from the adsorber 12 and passes down to the evaporator/condenser 13 which at this stage acts as a condenser and the water vapour is condensed evolving heat of condensation. The condensed water vapour is pumped by pump 19 via conduit 18 and non-return valve 20 to the water tank 14.

The heat of condensation is removed from the condenser 13 by silicone heat transfer liquid being circulated through countercurrent heat exchanger 28 by pump 33 via conduits 30 and 31 and valve 32. The other side of the countercurrent heat exchanger 28 receives heat and passes it to the domestic hot water system via conduits 29.

When the desorption is completed the adsorber 12 will be at the peak temperature of about 300°C and it therefore constitutes a high temperature heat store. By opening valve 27 and shutting valve 23 this stored heat may be released to the domestic circuit via heat exchanger 28 as required. During this phase valve 32 is shut and pump 33 is inoperative.

Once the temperature of the adsorber 12 has dropped to about 75°C it is available for the adsorption step.

When this occurs low temperature heat transfer fluid i.e. aqueous calcium chloride is passed through conduit 36 and through evaporator/condenser 13 acting as an evaporator and water from the water tank 14 is sprayed through sprayer 17 over the evaporator 13 by opening the valve 16. The water which drains from the evaporator 13 is pumped back to the water tank 14 by pump 19. That water which is evaporated is adsorbed by the Y-type zeolite molecular sieve adsorbent in the adsorber 12 and the heat of adsorption is transferred from the adsorber 12 to the domestic heating circuit via the countercurrent heat exchanger 28. This is achieved by circulating by circulation pump 24 the silicone heat transfer fluid in the conduits 26 and 22 with valve 23 shut and valve 27 open. If the rate of adsorption is toc high then the temperature of the adsorber 12 will rise and this rise can be controlled by shutting valve 16. If the valve 16 is kept shut then the heating system will gradually cool down but it may be re-activated as required (by re-opening valve 16) until the adsorption is complete.

These cycles of desorption and adsorption can be repeated indefinitely and it can be seen that the system is totally controlled during desorption and adsorption in a very simple manner.

CLAIMS

1. A heat pump unit comprising at least one tray which comprises a front sheet folded so as to form a series of partitions two sheet thick, extending away from the remaining portion of the sheet and a back sheet having a channel therein, said sheet being attached to the face of the front sheet remote from the partitions so that the channel together with said face of the front sheet forms a continuous passageway traversing a major proportion of that part of the area of the front sheet occupied by partitions.

2. A unit according to claim 1 wherein the front and back sheets are attached to but separated by a central sheet and wherein the continuous passageway is formed by the face of the central sheet remote from the partitions on the front sheet and the channel of the back sheet.

3. A heat pump unit comprising at least one tray, said tray comprising a central sheet attached to one face of which is front sheet slitted to enable the sheet to be folded upwards so as to form a series of partitions and attached to the other face of which is a back sheet having a channel therein which together with this other face forms a continuous passageway traversing a major proportion of that part of the area of the central sheet occupied by the enclosures formed between the partitions.

4. A unit according to any one of the preceding claims wherein the partitions are turned through aproximately a right angle before they terminate.

5. A unit according to claim 4 wherein the volumes bounded on three sides by the bent partition and the front sheet are occupied by matrices of metal fibres.

6. A unit according to any one of the preceding claims wherein the back sheet is extended and provided with a canopy with an inlet and outlet, the inlet and outlet connecting with the two ends of the passageway in the back sheet.

7. A unit according to any of the preceding claims which comprises between 15 and 25 trays stacked above each other.

8. A unit according to either of claims 6 and 7 wherein each tray is stacked in the adsorber so that the extended portions alternate in position and wherein there are four vertical pipes to carry the heat transfer fluid to and from the trays.

9. A heat pump unit according to claim 1 substantially as hereinbefore described with reference to Fig. 1 and 2 of the drawings.

10. A heat pump unit according to claim 4 substantially as hereinbefore described with reference to Fig. 3 to 7 of the drawings.

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